Interface Control Document

Boeing 727-200

Zero Gravity Corporation

December 2008

CHANGE RECORD		
Doc Version	**Date**	**Description**
Revision A	Dec 27, 2008	Major Revision
Revision A2	Jan 30, 2009	Minor Revision s including 2.1.5 Electrical Power and Interface

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1 INTRODUCTION

The Zero Gravity Corporation's (ZGC) program to support the National Aeronautics and Space Administration (NASA), provides a reduced gravity environment that can replicate the microgravity environment of space flight (0 g) as well as Lunar (1/6 g) , Martian, (1/3 g) or other reduced gravity levels. Increased or "hyper gravity" levels from 1.1 to 1.8 g can also be provided.

1.1 Purpose

The purpose of this Interface Control document is to provide a guideline for existing and potential users of the NASA Reduced Gravity Program. This document provides detailed interface definition, for the ZGC 727 aircraft.

1.2 Scope

This document applies to all NASA and NASA sponsored users of the Zero Gravity Corp. reduced gravity aircraft and only discusses the interfaces between the aircraft and equipment as well as services and data provided by the aircraft. Any questions about ground based services should be referred to the NASA Reduced Gravity Office (RGO) at:

NASA Reduced Gravity Office
Building 993
Ellington Field
Houston, TX 77034

Telephone: **(281) 244-9874** Fax: **(281) 244-9500**

1.3 References

AOD 33897, Experiment Design Requirements and Guidelines

National Electrical Manufacturers Association (NEMA)

1.4 List of Acronyms

A Amp
AC Alternating Current
AN Army/Navy
AOD Aircraft Operations Division
CST Central Standard Time
DC Direct Current

DIA Diameter
DOT Department of Transportation
F Fahrenheit
FAA Federal Aviation Administration
FS Fuselage Station
GFCI Ground Fault Circuit Interrupter
Hz Hertz
JSC Johnson Space Center
K Kelvin
LED Light Emitting Diode
MS Military Specification
MSDS Material Safety Data Sheet
NASA National Aeronautics and Space Administration
NEMA National Electrical Manufactures Association
PH Phase
PSI Pounds per Square Inch
PSIA Pounds per Square Inch Absolute
PSIG Pounds per Square Inch Gauge
RGO Reduced Gravity Office
SCFM Standard Cubic Feet per Minute
TBD To Be Determined
TEDP Test Equipment Data Package
V Volt
VAC Volts Alternating Current
VCR Video Cassette Recorder
VDC Volts Direct Current
ZGC Zero Gravity Corporation

2 FACILITIES PROVIDED

This section describes the aircraft capabilities and interfaces available to reduced gravity researchers and users of the ZGC B-727.

The reduced gravity environment is achieved by flying a modified Boeing 727 jet through a series of parabolic maneuvers. This results in short periods of less than one "g" acceleration. The lengths of these reduced gravity periods depend on the "g" level required for the specific test. Listed below are typical lengths for various maneuvers:

Hyper-g	Up to 1.8 g	60 seconds
Zero-g	0 g	17 seconds
Lunar-g	1/6 g (.16g)	20 seconds
Martian-g	1/3 g (.38g)	20 seconds

These maneuvers may be flown consecutively (i.e., roller coaster fashion) or separated by enough time to alter the test setup. Each parabola is initiated with a 1.8-g pull-up and terminated with a 1.8-g pullout. Normal missions, lasting approximately two hours, consist of 40 parabolic maneuvers, and originate and terminate at Ellington Field in Houston, Texas. Changes to the normal mission profile can be made to ensure more efficient test operations. These changes include number of parabolas performed, g level adjustments (i.e., .16, .38, .1, .5), and length of breaks between parabolas or sets of parabolas.

The B-727 aircraft test area is equipped with electrical power, an overboard vent, accelerometer data, and photographic-quality lights. NASA JSC can provide photographers for still photography and video coverage. Limited peer to peer wireless intercom may also available upon request. Portable compressed gas cylinder racks, for use on the B-727, can be provided by the RGO. Workspace is available on the ground for buildup and checkout of test equipment to ensure its operation before installation in the airplane.

Figure 1. B 727-200 Aircraft

2.1 Aircraft

*****NOTE: This section differs from the NASA C-9B information*****

The Boeing 727-200F is a three-engine, swept-wing aircraft specially modified for reduced gravity operations. The interior contains 38 seats for researchers in the rear of the aircraft and a research area approximately 67 feet long in the forward section of the cabin.

When operating for NASA, the ZGC B-727 is operated as a public aircraft within the meaning of the Federal Aviation Act of 1958, as amended. Although it does hold a current airworthiness certificate issued by the Federal Aviation Administration (FAA) and normally flies commercial flights for the general public, the operations for NASA are conducted under public use, which means that NASA is responsible for the airworthiness of the aircraft during NASA contracted flight operations. Consequently, any individual manifested to board the B-727 should determine before boarding whether their personal life or accident insurance provides coverage under such conditions. Also, since the aircraft will be used under test conditions, all researchers and test subjects will be fully informed of the test plans and all risks, hazards, and discomforts inherent to such tests prior to flight.

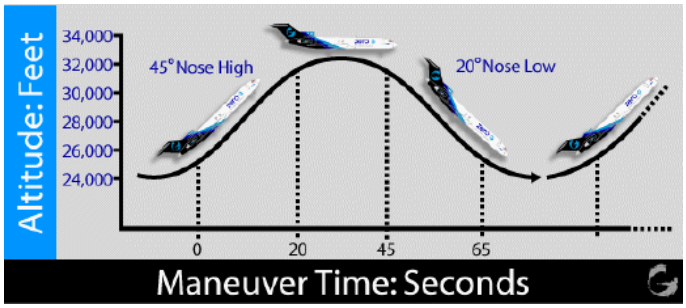

Figure 2. Parabola Diagram (for reference only)

2.1.1 Cabin Environment

Cabin pressure is maintained at an approximate pressure altitude of 8,000 feet (10.9 psia) during parabolic maneuvers. Loss of cabin pressurization could result in pressure as low as 3.3 psia; a factor that must be considered in the design of test equipment.

Normally, cabin temperature varies from 50 to 80 degrees Fahrenheit (F) in flight.

The temperature in the cabin is not controlled while the airplane is on the ground. Keep in mind that the aircraft is typically parked outside on the ramp during NASA operations at Ellington Field. Temperature ranges inside the cabin area can be as cold as 30°F during the winter months and as hot as 120°F in the summer. Researchers should make provisions for their experiment hardware to tolerate these conditions.

2.1.2 Cabin Dimensions

*****NOTE: This section differs from the NASA C-9B information*****

Approximately 67 feet of cabin length is available for test purposes. A floor plan schematic is shown in Figure 3. A cross sectional view of the cabin is shown in Figure 4. Test equipment is usually loaded through the cargo door, which is 90 inches high and 134 inches wide. A diagram of the cargo door is shown in Figure 5. A photograph showing the cargo door during loading operations is shown in Figure 6.

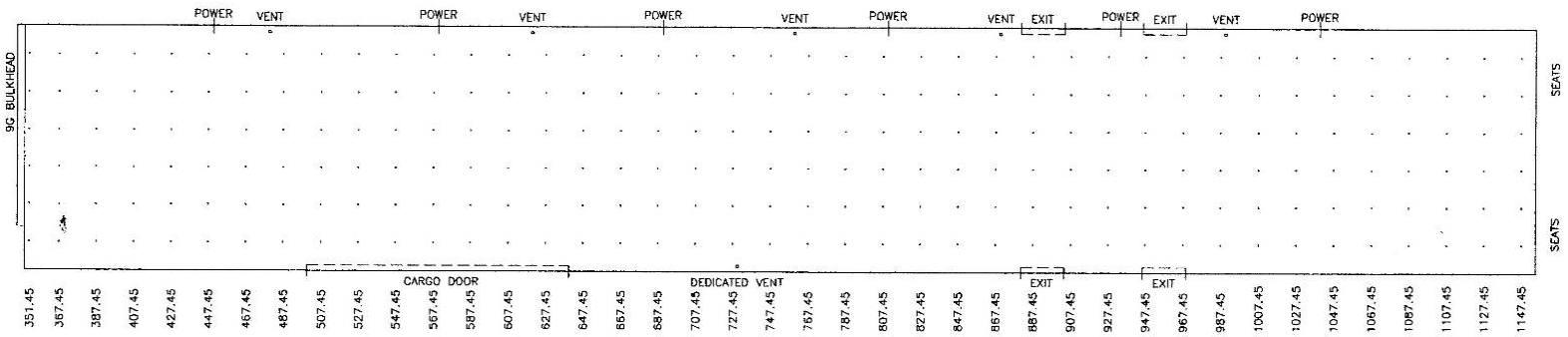

Figure 3. Aircraft Floor Layout

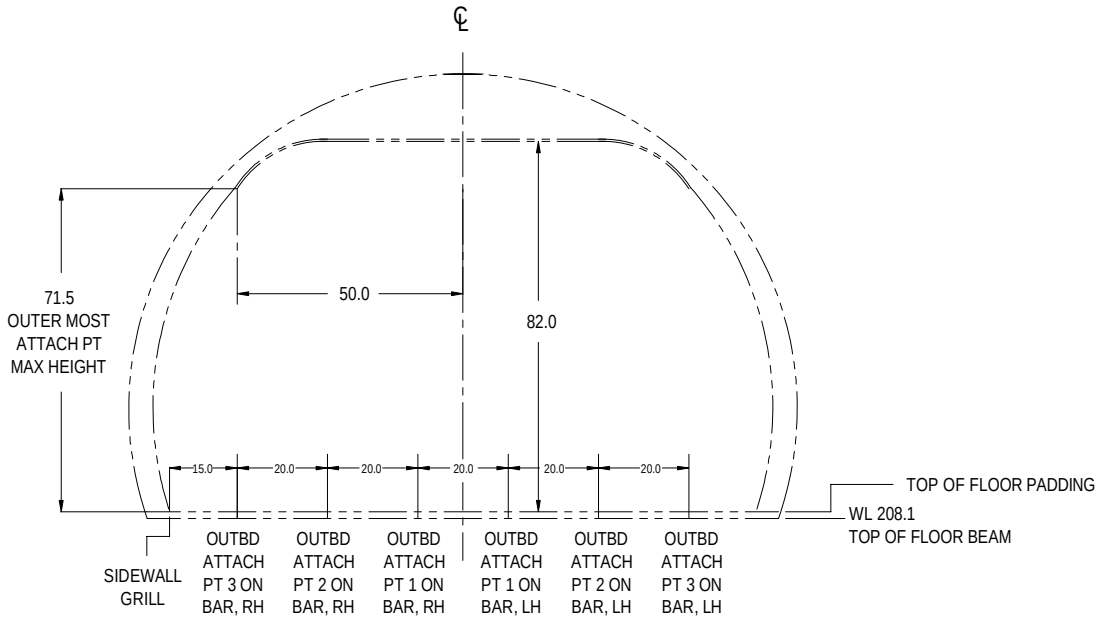

Figure 4. Cross-section of Fuselage

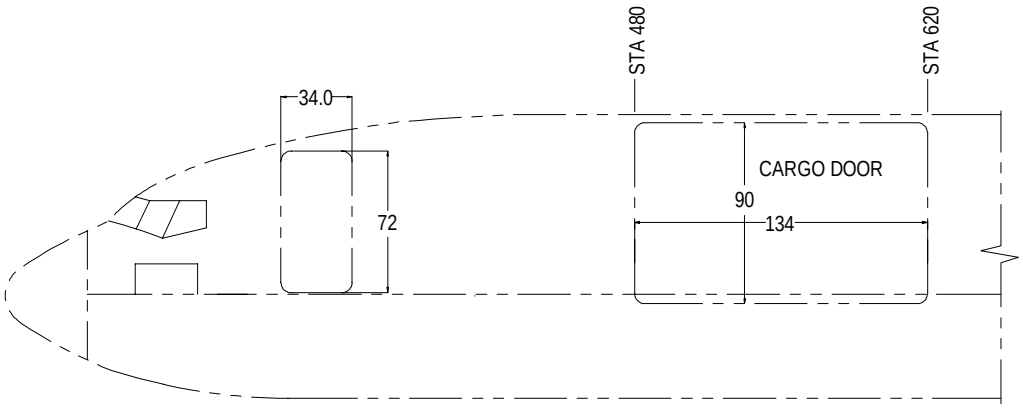

Figure 5. Cargo Door Dimensions in Inches

Figure 6. Cargo Door Operations

2.1.3 Floor Attachment Hardware/Loading

*****NOTE: This section differs from the NASA C-9B information*****

Research equipment will be mounted to the aircraft using attach points that are arranged in a 20" x 20" (+/- 1/16") grid on the aircraft floor (see figure 3 and 4). Typical payloads will use NASA bolt spacers (P/N EN 717081) to ensure rigid attachment of equipment that is flush with the padding on the aircraft floor. Both the aircraft floor and the spacer bolts have 3/8-24UNF threaded holes for experiment attachment. AN6 steel bolts, provided by the RGO, will be used to attach the research equipment to the bolt spacers or the aircraft floor.

When using the NASA bolt spacers the **tension allowable load for each attachment point is 2125 lbs** and the **shear allowable load is 2500 lbs**. Without the bolt spacers, the tension and shear allowable loads are each 2500 lbs. The aircraft floor padding must be removed when experiments are required to be bolted directly to the aircraft floor. All equipment to be bolted to the aircraft floor, either directly or with the bolt spacer, should be designed with a minimum of 4 aircraft attachment points. These 4 attachment points shall not be in a straight line. The RGO should be contacted in advance in all cases where less than 4 attachment points are required to attach a single piece of equipment.

The aircraft floor attachment points and spacer bolts shall not exceed the above stated capacities in tension or shear at anytime. These loads are not to be applied simultaneously.

Live loads shall not exceed **200** pounds per square foot during loading operations without the use of shoring, provided by ZGC, Reduced Gravity Office (RGO), and prior authorization by the Aircraft Operations Division (AOD) Engineering Branch.

Pneumatic tires should be used whenever possible for experiment handling on the aircraft. Use of steel or other hard wheels must be approved prior to use on the aircraft and for each specific case by the RGO and ZGC.

In flight loads shall be limited to **200** pounds per square foot without the use of shoring, provided by the RGO, and prior authorization by the aircraft operator.

Restraint	WLL	Width	Length	Fixed Length
CGU-1/B (strap)	#5000*	2 in	18 ft	12 in
S0203-0338-B (strap)	#1200	1.5 in	12 ft	14 in
104410P (strap)	#260	1 in	12 ft	8 in
AN-6 Steel Bolts	#5000*	3/8 in	1/2 to 4 in	N/A
Spacer Bolt EN 717081	#4100*	3/8 in	1.5 in	N/A

Table 1. Floor Attachment Hardware available from the RGO

No continuous equipment or structure greater than 8 feet in length shall be rigidly secured along the length of the aircraft deck.

2.1.4 Cabin Provisions

NOTE: This section differs from the NASA C-9B information*

The aircraft is equipped with **38** seats aft of the test section. A private area is available where you can use disposable waste collection devices. The interior walls and floor of the cabin are covered with foam padding for the protection of personnel and equipment.

2.1.5 Electrical Power and Interface

NOTE: This section differs from the NASA C-9B information*

Five types of electrical power are available, as shown in Table 2. Each experiment will be allotted a portion of the power budget by the RGO. Special arrangements can be made for experiments with unusually high power requirements.

Power Type	Total Current Available
28 Volts Direct Current (VDC)	120 Amps
115 Volt AC, 400 Hertz (Hz), Three Phase	35 Amps
115 Volt AC, 60 Hz, Three Phase	30 Amps*
115 Volt AC, 60 Hz, Single Phase	150 Amps*
230 Volt AC, 60 Hz, Single Phase	30 Amps *

** The combined total current draw for 115VAC 3 phase, 115VAC, single phase, and 230VAC single phase is limited to 150 Amps*

Table 2. Total Electrical Test Power

Aircraft electrical power is distributed via six power distribution panels evenly distributed along the lower right sidewall of the research cabin. A photo of a power distribution panel is shown in Figure 7. Table 3 lists the power distribution panel configuration and specifications. The following sections will explain the mechanical interface to each type of electrical power. The power distribution panel receptacles are all female and experimenters must provide the mating male plug connectors. Each electrical cable from a power distribution panel shall include a current limiting device on the experiment.

Figure 7. Example of a Power Distribution Panel (Panel 1)

Panel	Voltage	Freq.	Phase	Max Current	Use Mating Connector	GFCI Extension Cord Provided?
1 & 4	115 VAC	60 Hz	Single	20 A	NEMA 5-20P	Yes
	115 VAC	60 Hz	Single	20 A	NEMA 5-20P	Yes
	115 VAC	60 Hz	Single	20 A	NEMA 5-20P	Yes
	28 VDC	DC	DC	15 A	MS3456W16-10P	No
	28 VDC	DC	DC	15 A	MS3456W16-10P	No
	28 VDC	DC	DC	15 A	MS3456W16-10P	No
	28 VDC	DC	DC	35 A	MS3456W20-14P	No
	115 VAC	400 Hz	Three	35 A	MS3456W22-22P	No
2 & 5	115 VAC	60 Hz	Single	20 A	NEMA 5-20P	Yes
	115 VAC	60 Hz	Single	20 A	NEMA 5-20P	Yes
	115 VAC	60 Hz	Single	20 A	NEMA 5-20P	Yes
	28 VDC	DC	DC	15 A	MS3456W16-10P	No
	28 VDC	DC	DC	15 A	MS3456W16-10P	No
	28 VDC	DC	DC	15 A	MS3456W16-10P	No
	115 VAC	60 Hz	Three	20 A	NEMA L21-20P	Yes
	115 VAC	60 Hz	Single	30 A	NEMA L5-30P	Yes
3 & 6	115 VAC	60 Hz	Single	20 A	NEMA 5-20P	Yes
	115 VAC	60 Hz	Single	20 A	NEMA 5-20P	Yes
	115 VAC	60 Hz	Single	20 A	NEMA 5-20P	Yes
	28 VDC	DC	DC	15 A	MS3456W16-10P	No
	28 VDC	DC	DC	15 A	MS3456W16-10P	No
	28 VDC	DC	DC	15 A	MS3456W16-10P	No
	230 VAC	60 Hz	Single	20 A	NEMA L14-20P	Yes

Table 3. Power Distribution Panel Specifications

28 VDC

Three 28VDC, 15 Amp circuits are provided at each power distribution panel and one 35 Amp circuit is provided at power panels 1 and 4. All 28 Volt interfaces use standard Military Specification (MS) cannon connectors as shown in Figure 8. See Figure 9 for examples of these power panel receptacles.

Figure 8. MS Cannon Receptacle (Left) and Plug (Right)

The 28VDC power is not a high accuracy, scientific grade, power system. The 28VDC output voltage can vary from 25VDC to 29VDC, +/- 4.5% RMS ripple, based on the load. Furthermore, the 28VDC transformer/rectifiers require a minimum of a 3 Amp load. If higher voltage accuracy and/or regulation is required the experiment should contain the appropriate hardware and be designed accordingly.

Experimenters must use wire sizes in accordance with "Minimum Wire Gauges" (AOD 33897, Table 2) and must provide the following mating male plug connectors:

- MS3456W16-10P to connect to the 15 Amp circuit.
- MS3456W20-14P to connect to the 35 Amp circuit.

	15 A	35A
HOT	A	A
GROUND	C	B

Connector Pin Out for 28VDC connections

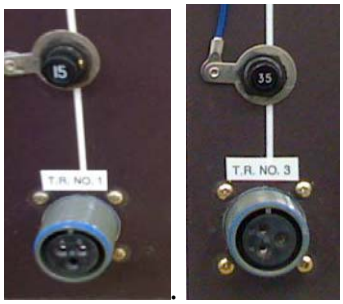

Figure 9. Example of 28 VDC 15 A and 35 A receptacles uncapped

115 VAC, 60 Hz, Single Phase (ph), 30 A and 20 A

Three 115VAC, 60 Hz, 20 Amp circuits are provided at each power distribution panel and one 30 Amp circuit is provided at power panels 2 and 5. Research hardware interfaces to these receptacles are via 6 foot long Ground Fault Circuit Interrupter (GFCI)-protected single receptacle pigtails as shown in Figures 10 and 10A. The GFCI-protected pigtails terminate in either a 20 Amp flat prong (NEMA 5-20R) or a 30 Amp twist lock (NEMA L5-30R) standard type residential outlet as listed in Table 3.

Experimenters must use wire sizes in accordance with "Minimum Wire Gauges" (AOD 33897, Table 2) and must provide the following mating male plug connectors:

- NEMA 5-20P to connect to the 20 Amp circuit.
- NEMA L5-30P to connect to the 30 Amp circuit.

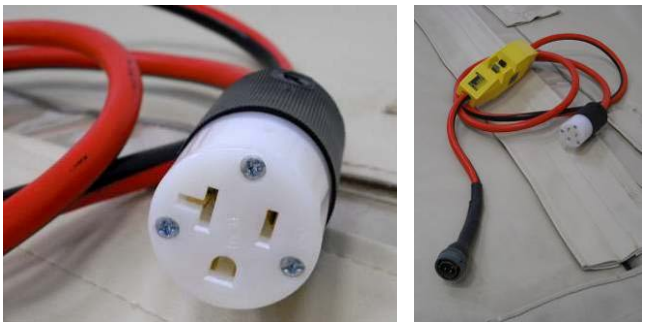

Figure 10. Example of 115Vac 60Hz (20A) GFCI-protected Pigtail

Figure 10A. Example of 115Vac 60Hz (30A) GFCI-protected Pigtail

115 VAC, 60 Hz, 3 Phase

One 115VAC, 60Hz, 3 Phase, 20 Amp circuit is provided at power panels 2 and 5. Research hardware interfaces to these receptacles are via 6 foot long Ground Fault Circuit Interrupter (GFCI)-protected single receptacle pigtails, as shown in Figure 12. The GFCI-protected pigtails terminate in a 20 Amp, 5-pin, twist lock (NEMA L21-20R) receptacle.

It is the responsibility of the researcher to ensure their equipment is properly designed to protect the hardware from electrical faults including a loss of phase synchronization or total loss of one phase of electrical power.

Experimenters must use wire sizes in accordance with "Minimum Wire Gauges" (AOD 33897, Table 2) and must provide the following mating male plug connector:

- NEMA L21-20P

Figure 12. Example of L21-20P connector available on the 115 VAC 60 Hz 3 ph 20A GFCI-protected Pigtail

115 VAC 400 Hz, 3 Phase

One 115VAC, 400 Hz, 3 Phase, 35 Amp circuit is provided at power panels 1 and 4. See Figure 11 for an example of this receptacle. All 115 VAC, 400Hz interfaces use standard Military Specification (MS) cannon connectors as shown in Figure 8.

It is the responsibility of the researcher to ensure their equipment is properly designed to protect the hardware from electrical faults, including a loss of phase synchronization or total loss of one phase of electrical power.

Experimenters must use wire sizes in accordance with "Minimum Wire Gauges" (AOD 33897, Table 2) and must provide the following mating male plug connector:

- MS3456W22-22P

Phase 1	A
Phase 2	B
Phase 3	C
Ground	D

Connector Pin Out for 115 VAC, 400 Hz, 3 ph connections

Figure 11. Example of 115 VAC 400 Hz 3-ph receptacle

230 VAC, 60 Hz, Single ph, 20 A

One 230VAC, 60Hz, 20 Amp circuit is provided at power panels 3 and 6. Research hardware interfaces to these receptacles are via 6 foot long Ground Fault Circuit Interrupter (GFCI)-protected single receptacle pigtails as shown in Figure 13. The GFCI-protected pigtails terminate in a 20 Amp, 4-pin, twist lock (NEMA L14-20R) receptacle.

It is the responsibility of the researcher to ensure their equipment is properly designed to protect the hardware from electrical faults including a loss of phase synchronization or total loss of one phase of electrical power.

Experimenters must use wire sizes in accordance with "Minimum Wire Gauges" (AOD 33897, Table 2) and must provide the following mating male plug connector:

- NEMA L14-20P

Figure 13. Example of L14-20P connector available on the 230 VAC 60 Hz Connector (20 A) GFCI-protected Pigtail

2.1.6 Aircraft Lighting

The aircraft cabin contains 23 light emitting diode (LED) photo-lights (down both sides/overhead). These lights have been specially designed to provide sunlight-quality illumination [color temp of 5,600 Kelvin (K)]. Because of the unique design of the assemblies, daylight camera film may be used in the cabin and a flashbulb is typically not required.

2.1.7 High Pressure Gas System

High pressure gas systems are allowed for use on the B-727 through compliance with all NASA safety guidelines. All pressurized gas systems must receive approval through the pressure vessel certification procedure documented in the RGO User's Guide (refer to AOD 33897, Section 2.3).

The High Pressure Gas Cylinder Racks are provided by the RGO. These racks except only commercial DOT gas cylinders, measuring 9 inches in diameter and 55 inches in length. Please contact the RGO for information and to request high pressure gas and K-bottle handling equipment.

NOTE :*Bottle Racks must be included in Researcher Test Equipment Data Package (TEDP) for overall loading and configuration.*

ZGC does not supply regulators, relief valves, or hoses to researchers.

Any high-pressure gas equipment must be approved for use by the RGO prior to its arrival at Ellington Field (refer to AOD 33897, Section 2.3).

2.1.8 Overboard Vent System

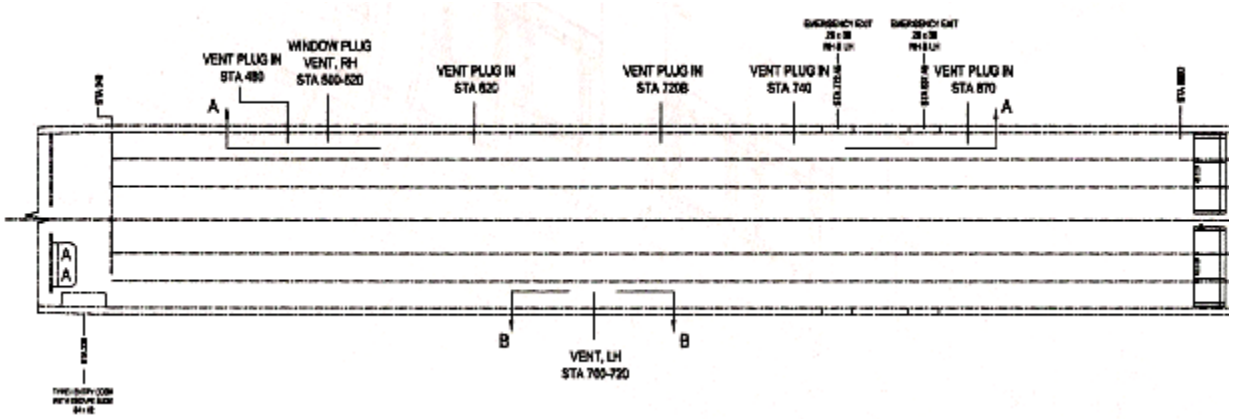

Figure 14. Overboard Vent System Layout

An overboard vent system is available on the aircraft for the venting of most gases. No liquid can be vented through this system due to freezing that could occur at altitude.

There are two 1-inch diameter (DIA) vent lines (see Figure 15): one is a multi-user line and one is a dedicated line. The multi-use vent lines are on the right side of the aircraft looking forward and have 5 interface locations at fuselage station (FS)480, 620, 720B, 740, 870. The dedicated vent line has a single port for use with oxygen enriched or otherwise reactive gases, and is located on the left side of the fuselage between stations 700 and 720.

Figure 15. Multi-User Overboard Vent (shown capped and covered)

The fittings on the multi-user vent line are male Army/Navy (AN) 16 fittings (1 inch); researchers must supply a female AN 16 fitting on the research equipment (Parker Triplelok 37 degree Flared Tube Fitting).

NOTE: *All vent line materials must be compatible with expected vent mixtures.*

When the vent line is being utilized for an oxygen enriched gas mixture, the vent line must meet the requirements for oxygen clean systems. Proper written oxygen handling procedures must be used at all times and approved by the RGO before use.

The dedicated vent port has a male 1-inch AN 16 fitting. The researcher is responsible for providing all of the appropriate fittings and hoses from the aircraft connection to their research equipment.

A simplified table of vent line flow rates is provided below:

Location	Max Flow (SCFM) 36,000'	Min Flow (SCFM) 26,000'
Fwd Manifold	TBD (total*)	TBD (total*)
Aft Manifold	TBD (total*)	TBD (total*)
Dedicated Line	TBD	TBD

Table 4. Flow Rates

* Total refers to a combination of all experiment flows at that location including all flows introduced upstream at the forward manifold.

NOTE: *These rates apply at the manifold/fitting only. Line losses in researcher equipment must be considered to determine flow rate at researcher's termination point.*

A complete study of the volumetric flow rates through the overboard vent system will be performed and a copy available through the RGO.

2.1.9 Aircraft G-Load Display

There are two display panels to show the real-time g-value and the parabola count for reference only. One display is mounted on the forward bulkhead facing aft and the other is mounted at the aft end of the research area, behind the seats, facing forward. These values are typically recorded in flight by ZGC and are provided to the RGO within 7 days after the conclusion of a flight week. Requests for the raw gravity level data can be made to the RGO.

2.1.10 Accelerometer Signal

*****NOTE: This section differs from the NASA C-9B information*****

The aircraft accelerometer system provides six analog outputs available to researchers. The signals are available from six DB-15 female connectors, each of which provide 3 axis acceleration signals (Gx, Gy, and Gz) and corresponding accelerometer temperature signals (Tx. Ty, and Tz). The signal distribution connectors are located through the length of the research cabin on the left side of the fuselage, opposite of the power panels. Each signal distribution box is buffered to prevent interference with aircraft systems and other researchers.

Each signal is filtered with a normal cutoff frequency of 25 Hz.

A male DB-15 connector and 10- to 15-feet of signal cable are required to connect to a signal distribution box. Pin designations are shown in Figure 16 and Table 5. The voltage to acceleration conversion formula and the calibration coefficients, which change annually, will be provided by the RGO upon request.

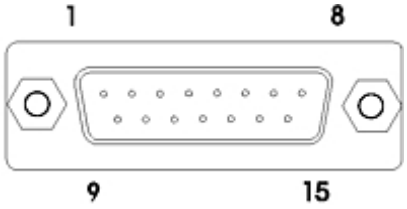

Figure 16. DB-15 Accelerometer Data Connector

Measurement	Pin Number	Signal Value
Gx +	5	0-10 VDC
Gx -	9	Common
Gy +	6	0-10 VDC
Gy -	10	Common
Gz +	4	0-10 VDC
Gz -	11	Common
Tx +	1	0-5 VDC
Tx -	12	Common
Ty +	2	0-5 VDC
Ty -	13	Common
Tz +	3	0-5 VDC
Tz -	14	Common

Table 5. Accelerometer Pin Designations (DB-15)

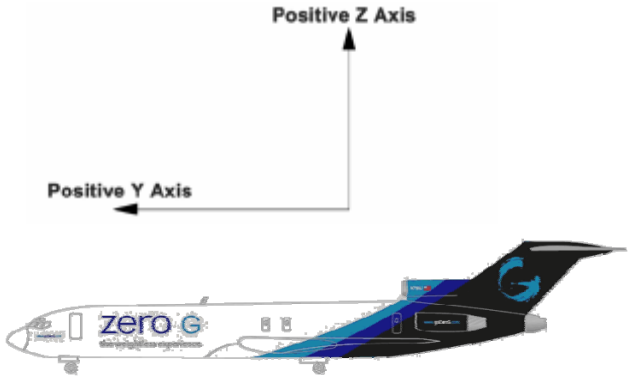

Figure 17. Aircraft Acceleration Vectors

2.1.11 On-Board Tools

The RGO maintains a toolbox with a collection of hand tools sufficient to install most test packages in the aircraft. No tools or loose equipment are allowed on the aircraft at any time without proper inventory control and specific prior authorization of RGO. The toolbox and all tools are removed prior to flight unless specifically authorized. This includes user supplied items; there are no exceptions. **No tools are provided during flight.** Refer to AOD 33897, Section 2.10 for a description of allowed tools.

2.1.12 On-Board Storage Containers

*****NOTE: This section differs from the NASA C-9B information*****

The 727 does not have any overhead or under seat storage capacity for laptops, cameras, bags, or other ancillary research equipment.

The RGO has three storage containers for use on the aircraft by researchers *upon request.* Include your stowage needs request in your TEDP to ensure storage container availability. Examples of the two smaller containers and one large container are shown in Figure 18.

Figure 18. On-Aircraft Storage Containers

The interior dimensions and take-off / landing weight limits are as follows:

- Small container: 20-1/2 x 19 x 19-1/2 inches (L x W x H), 100 pounds.
- Larger container: 46-1/2 x 22-1/2 x 17-1/2 inches (L x W x H), 150 pounds.

2.2 Ground Facilities

Zero Gravity Corporation does not provide any ground facilities or equipment for NASA sponsored flights from Ellington Field. Please refer to NASA document AOD 33912, Rev. B for information on ground facilities and equipment provided by the RGO.